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USE OF TCS3200 SENSOR TO IDENTIFY HEAVY METAL MATERIALS

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ABSTRACT

Heavy metals are natural components that are toxic and can endanger living things even in a very small concentration. Water that is polluted by heavy metals in a certain concentration can harm the ecosystem and can be fatal if entered the human organ system. The principle of heavy metal concentration measurement using the TCS3200 sensor is a sensor will sense the color gradation from dissolved heavy metal. This color gradation will be calibrated to a concentration of dissolved heavy metals. Heavy metal material that is used for this research were FeCl3, NiSO4, and CuSO4. Based on the analysis results, there were 4 results obtained. The first one was performance specification from this instrument consists of a TCS3200 sensor, black acrylic box for the sensor placement. In the black acrylic box, there was a hole sample for sample placement. The second result was the effect of changing in heavy metal concentration to sensors output data is proportional. The third result was an instrument calibrating with existing data. The fourth result was accuracy and precision from the instrument which have been calibrated. For FeCl3 material, the average accuracy was 95.5% and precision was 98.7%. For NiSO4, the average accuracy was 96% and precision was 98.3%. For CuSO4 material, the average accuracy was 99.7% and precision was 99.8%.

Keywords : TCS3200, Heavy Metals, Arduino Microcontroller.

I. INTRODUCTION

Heavy metals are natural components of soil. Heavy metals are called dangerous because they generally have a high density (5 g / cm3) and small concentrations can be toxic and dangerous [1]. This heavy metal element can harm living things if it enters the body of living things even in small concentrations. Some examples of heavy metals are Zn, Cu, Fe, Co, and Mn.

Metals contained in industrial waste are the main source of metal hydrosphere pollution. Another source is the movement of drainage water from catchments that have been contaminated by waste from mining and smelting units. In general, metal ion toxicity to mammalian systems is caused by the chemical reactivity of ions with cellular structural proteins, enzymes, and membrane systems [2].

The development of science and technology in humans can be able to produce a natural thing into something useful and can be developed with a variety of innovations and continue to conduct research to produce technology products to meet human needs. The science and technology results have proven to provide many facilities and benefits for humans [3].

The development of electronic technology is inseparable from the presence of sensors as an important component in making tools. In general, sensors are better known as devices that can convert physical quantities such as radiation, magnetic, thermal, mechanical, and chemical into electrical quantities as outputs [4]. The sensors used in the manufacture of the tools vary and are adapted to the use of the sensors themselves. One of the sensors commonly used is an optical sensor. Optical sensors function to capture light rays and convert them into voltage [5].

TCS3200 is an IC that converts light colors to frequency values and this sensor has the facility to record up to 25 different color data [6].TCS3200 color sensor is a color sensor that is often used in microcontroller applications to detect an object or the color of the object being monitored.

The TCS3200 color sensor is a series of photodiodes arranged in an 8x8 matrix array with 16 photodiode configurations that function as red filters, 16 photodiodes as blue filters, and 16 more photodiodes without color filters. The TCS3200 color sensor works by reading the value of the light intensity emitted by the super bright led to the object, the reading of the light intensity value is done through an 8x8 photodiode matrix, where the 64 photodiodes are divided into 4 groups of color readers, each color illuminated by the led will reflect light led to the photodiode, the reflection of the light has a different wavelength depending on the color of the object detected, this is what makes the TCS3200 color sensor able to read several kinds of colors[7].

The photodiode sensor is a sensor that is sensitive to light (photodetector), where this sensor will receive a change in the current if it receives light intensity. The current flowing on the sensor is in accordance with the concept of a diode in general. The electric current will be forward-biased if the anode part of the diode is given a positive voltage and the cathode is given a negative voltage. Changes in current will affect the voltage [8].

II. METHOD

Based on the problems raised, this research belongs to research and development (Research and Development). Research and development functions are to develop existing products and to create products that have never existed before. Research and development is a scientific way to research, design, manufacture, and test products that have been produced [9]. The research and development procedure in this study can be seen in Figure 1.

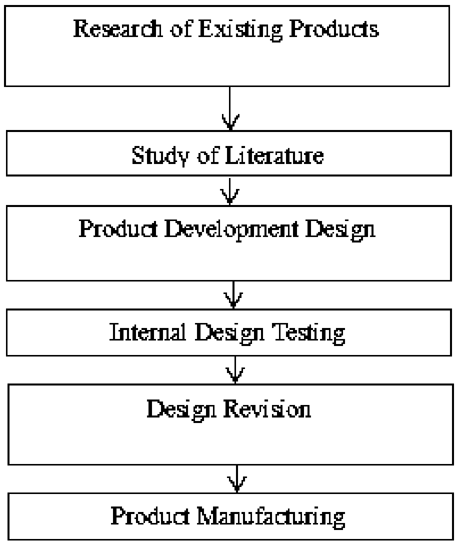


Fig. 1. R&D research procedures

In 2013, Hariyadi Singgih conducted research on a formalin measuring instrument using the TCS3200 sensor with the title Formalin Content Test in Salted Fish Using a Color Sensor with FMR Assistance. This study has a drawback, namely that it cannot measure the formalin concentration that is too small and too large, namely <10ppm and> 60ppm. This study only uses the red filter on the TCS3200 sensor because the red filter responds well.

In 2017, a study was conducted on a heavy metal measuring instrument with the title Chromium (VI) Heavy Metal Level Testing System in Water Using an Arduino Uno Microcontroller Based LDR Light Sensor The drawback of this study is that it only measures chromium heavy metal levels.

Literature studies are carried out by browsing several books, journals, and other sources that are relevant and supportive heavy metal identification using the TCS3200 sensor.

At the product development planning stage, the result is a complete product with specifications. The design of this tool is in the form of a black box with the intention that the light that will be forwarded to the sensor will not affect the light from outside. This tool system consists of a power supply circuit, a TCS3200 sensor circuit, and a microcontroller circuit. The design of the tool can be seen in Figure 2.

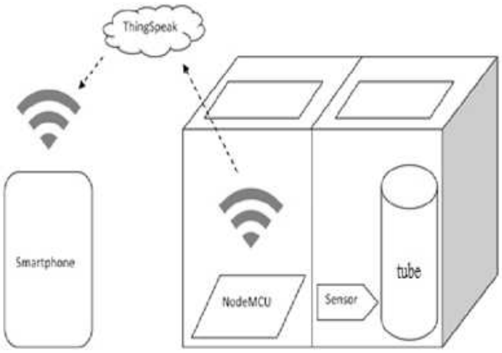


Fig. 2. Initial product design

In the box on the left is the place for Arduino as programming, while the right is the box where the test tube is a container for sample solutions, and the TCS3200 sensor is a detector. In the box, the sensor and test tubes will be placed opposite. The way the tool works is when the tool is turned on, the TCS3200 sensor will turn on and will shoot light into the sample. Light hitting the sample will be reflected in the sensor. The light that will be reflected by the sample will vary in intensity depending on the color and concentration. The color intensity of the solution can be detected by the TCS3200 sensor. The block diagram of the electrical conductivity control system can be seen in Figure 3.

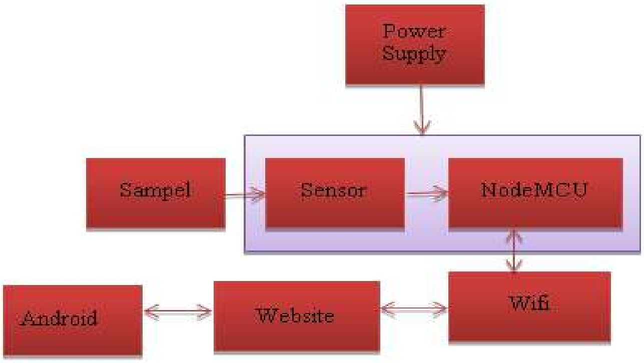
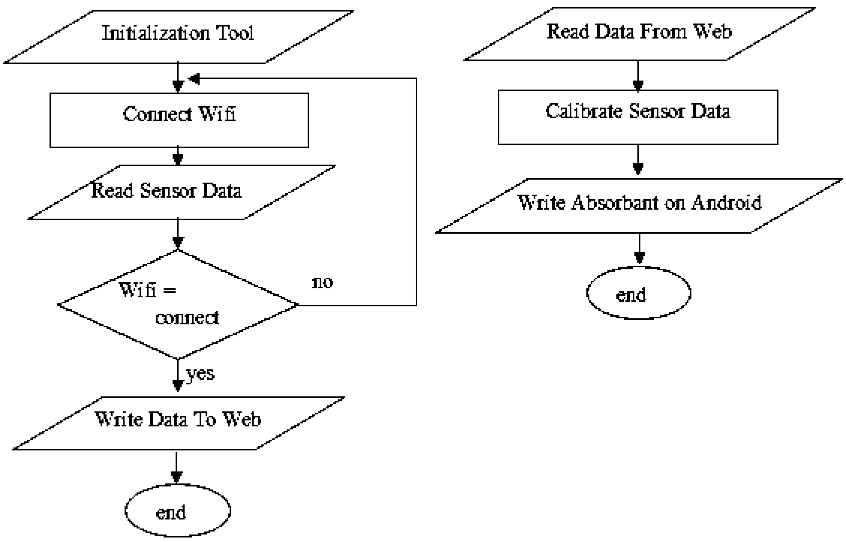


Fig. 3. Measurement system block diagram

Based on Figure 3 it can be explained that the power supply is required to activate the NodeMCU. The sensor will measure the color degradation of the sample and the data will be received by NodeMCU. The colorimeter system flowchart can be seen in Figure 4.



(a) (b)

Fig. 4. (a) Flowchart arduino colorimeter system and (b) flowchart android system

After the tool initialization is complete, nodeMCU will search for the specified wifi network. Then the sensor will read the data from the sample and send the sample data to the website. If the specified wifi is lost or disconnected, nodeMCU will search for the wifi network again.

Android can read data from the web. Data that is on the web is then calibrated on Android. After selecting the sample used, the sample absorbance you want will be displayed on Android.

The design validation test of the design of the calorimeter tool system is carried out so that the colorimeter system is made to run well.

After the validation test was carried out, there were several design revisions to make the tool even better. These suggestions include reducing the mechanical design of the device, replacing the power supply with a battery, and reducing the sample size. It is felt that the mechanical design of the tool can still be minimized so that it is easier to carry. Replacement of the power supply with a battery is intended so that the measurement does not depend on PLN electricity and can be used anywhere. The sampling place is minimized because the place where the sample was previously very large was a 100ml beaker and changed to a 20ml sample tube.

The revised product consists of an acrylic box containing a sensor, NodeMCU, and a battery bay. At the top of the acrylic, a box is given a hole to enter the sample holder. The mechanical design of the calorimeter system can be seen in Figure 5.

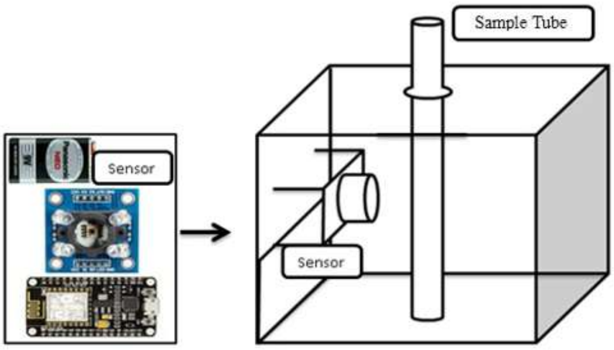


Fig. 5. Colorimeter instrument mechanical design

Based on Figure 5 is a modification of the initial design of the calorimeter tool. On top of the acrylic box, there is only a hole for the sample entry and there is no more box for nodeMCU as in the initial design. NodeMCU is placed under the sensor and the battery is placed above the sensor to minimize space.

III. RESULTS AND DISCUSSION

A. Research result

1. Colorimeter System Performance Specifications.

The colorimeter system performance specifications consist of a TCS3200 sensor, NodeMCU, and battery. The layout of the TCS3200, NodeMCU, and battery sensors can be seen in Figure 6.

Fig. 6. Position of sensor in acrylic box

Figure 6 is the location of the sensor in an acrylic box. The placement of the sensor is the same as the placement of the NodeMCU and the battery which aims to minimize space and facilitate mechanical installation. The purpose of using the battery is that it can be used anywhere and anytime, it does not depend on PLN electricity.

2. Effect of Heavy Metal Concentrations on Sensor Output Data

The solvent used to dissolve FeCl3 powder is Aquades. The concentration of the mother liquor used for the FeCl3 solution, namely 5gr FeCl3 powder, was dissolved in 100ml of Aquades. The molarity of the mother liquor FeCl3 is 0.4M. The color of this FeCl3 sample is red. So in this FeCl3 sample, the sensor setting uses the red filter setting. The effect of the concentration of heavy metal solutions on the output data can be seen in Figure 7.

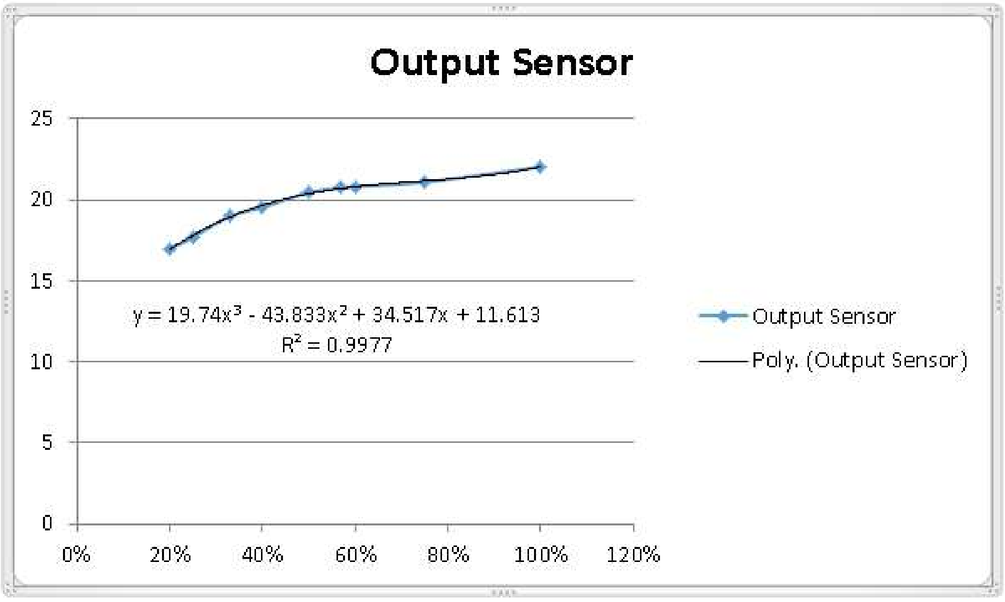


Fig. 7. Effect of heavy metal FeCl 3 concentration on sensor output data

The solvent used to dissolve NiSO4 powder is Aquades. Initially, the concentration of the mother liquor used for the NiSO4 solution, namely 5gr NiSO4 powder, was dissolved in 100ml of Aquades. However, because the main solution was too clear, a NiSO4 solution of 200% of the original main solution, which contained 5gr of NiSO4 powder, was dissolved in 50ml of Aquades. The molarity of the NiSO4 mother liquor is 0.32M. The color of this NiSO4 sample is green. So in this NiSO4 sample, the settings on the sensor use a green filter setting. The effect of the concentration of the NiSO4 heavy metal solution on the sensor output data can be seen in Figure 8.

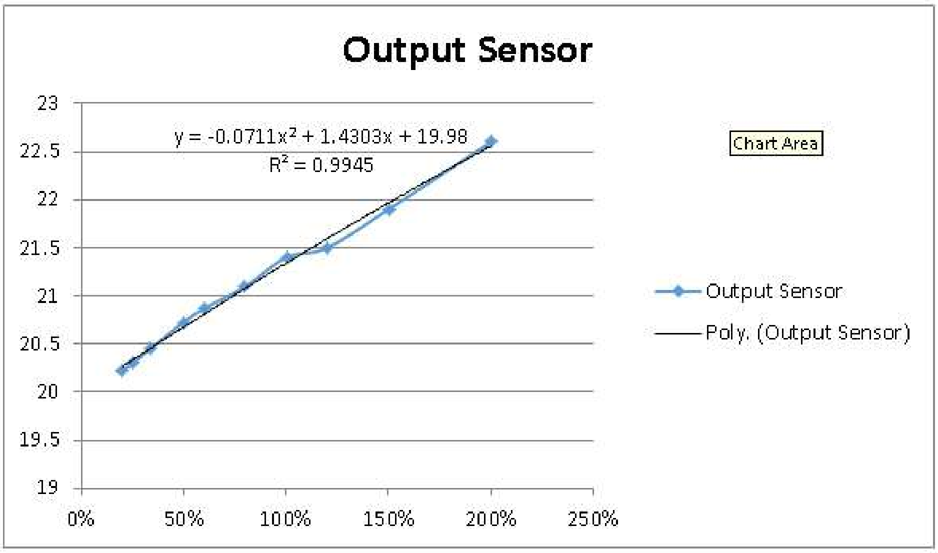


Fig. 8.The effect of the concentration of NiSO4 heavy metal solution on the sensor output data

The solvent used to dissolve CuSO4 powder is Aquades. Initially, the concentration of the mother liquor used for CuSO4 solution, namely 5gr CuSO4 powder, was dissolved in 50ml of Aquades. The molarity of the CuSO4 mother liquor is 0.625M. The color of this CuSO4 sample is blue. So in this CuSO4 sample, the sensor setting uses a blue filter setting. The effect of heavy metal solution concentration on sensor output data can be seen in Figure 9.

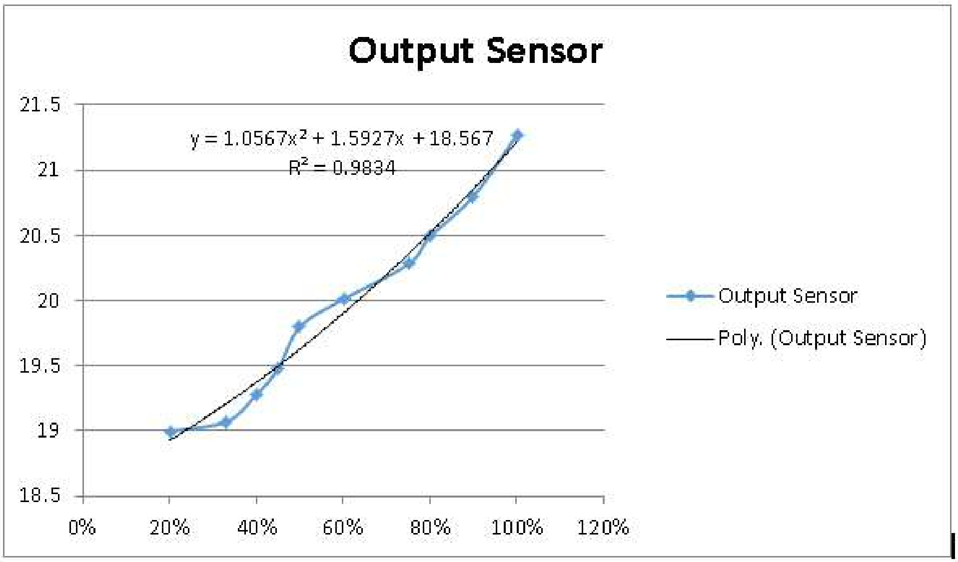


Fig. 9. Effect of heavy metal solution concentration on absorbance

3. Colorimeter System Accuracy and Accuracy

Calibration of measuring instruments is an important thing to do so that the data on the measuring instrument can be used. Calibration is a series of activities to compare or form a relationship between a measurement system with known values or quantities that have been measured under certain conditions. The tool calibration process is carried out for the three materials.

The accuracy of the measurement data is obtained from the comparison between the colorimeter and the standard measuring instrument. The accuracy data is obtained from the distribution of data on repeated measurements.

a. The accuracy data for the FeCl3 material ranges from 91.6% to 99.5% with an average accuracy of 95.5%. Accuracy data with 10 repeated measurements, ranging from 97.6% to 99.6% with an average accuracy of 98.7%

b. The accuracy data for NiSO4 material ranges from 94.4% to 98.2% with an average accuracy of 96%. Accuracy data with 10 repeated measurements, ranging from 97% to 99.9% with an average accuracy, namely 98.3%.
c. The accuracy data for CuSO4 material ranges from 99.4% to 99.9% with an average accuracy of 99.7%. Accuracy data with 10 repeated measurements, ranging from 99.6% to 99.99% with an average accuracy of 99.8%.

B. Discussion

The results of the research carried out can be obtained, namely the performance specifications of the colorimeter system, the effect of the concentration of heavy metal solutions with absorbents, the effect of the concentration of heavy metal solutions with sensor output data, the calibration of the sensor output on the concentration of heavy metals, and the accuracy and accuracy of the colorimeter system. The activities carried out before conducting the research started from literature study, tool preparation, to tool testing.

The first result that has been achieved in this study is the performance specification of the calorimeter system. In the calorimeter system, performance specifications consist of a TCS3200 sensor, an acrylic toolbox. The output on the TCS3200 sensor is a frequency. The TCS3200 sensor has an 8 x 8 photodiode sensor array. The array on the photodiode sensor is divided into 4 parts, namely the red filter, green filter, blue filter, and no filter (clear).

The results of the performance specifications of the colorimeter system can explain the function of each component used. The acrylic used in the box is black acrylic. Acrylic is black in color so that the LED on the sensor cannot be absorbed by the acrylic wall so that it does not affect the measurement.

The second result that has been achieved in this study is the effect of heavy metal concentrations on sensor output data. Measurements were made with 10 variations for each sample. It was found that the smaller the heavy metal concentration, the smaller the sensor output data obtained. The TCS3200 sensor output data on the colorimeter is read on an android. The effect of heavy metal concentrations on sensor output data is plotted in a graphical form which produces an equation.

The third result that has been achieved in this study is the calibration of the effect of the concentration of heavy metal solutions on the sensor output data. The calibration was carried out on 3 samples, namely FeCl3. NiSO4, and CuSO4. The effect of the concentration of heavy metal solutions on the sensor output is plotted in a graphical form which produces an equation. This equation is used as a calibration equation.

The fourth result is the accuracy and accuracy of the tool. It was found that each sample had different precision and accuracy. For FeCl3 material, the accuracy ranges from 91.6% to 99.5% with an average accuracy of 95.5%. The accuracy data for the FeCl3 material ranges from 97.6% to 99.6% with an average accuracy of 98.7%. For NiSO4 material, the accuracy of the coarse range is 94.4% to 98.2% with an average accuracy of 96%. Accuracy data for NiSO4 material ranges from 97% to 99.9% with an average accuracy of 98.3%. For CuSO4 material, the accuracy ranges from 99.5% to 99.9% with an average accuracy of 99.7%. Accuracy data for CuSO4 material ranges from 99.6% to 99.99% with an average accuracy of 99.8%

IV. CONCLUSION

Based on the results of testing and data analysis and discussion of the colorimeter system, several conclusions were obtained, namely:

1. The results of the performance specifications of the colorimeter system consist of the TCS3200 sensor, battery, acrylic box, website, and android.
2. The effect of changes in the concentration of heavy metal solutions on the sensor output data is linear. The greater the concentration of the heavy metal solution, the greater the sensor output data.
3. The design specifications of the colorimeter system include precision and precision. The precision and precision of each material is different. For FeCl3 material, the accuracy ranges from 91.6% to 99.5% with an average accuracy of 95.5%. Accuracy data for FeCl3 material ranges from 97.6% to 99.6% with an average accuracy of 98.7%. For NiSO4 material, the accuracy of the coarse range is between 94.4% to 98.2% with an average accuracy of 96%. Accuracy data for NiSO4 material ranges from 97% to 99.9% with an average accuracy of 98.3%. For CuSO4 material, the accuracy ranges from 99.5% to 99.9% with an average accuracy of 99.7%. Accuracy data for CuSO4 material ranges from 99.6% to 99.99% with an average accuracy of 99.8%.

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